

**BASIC ELECTRICITY  
AND ELECTRONICS**

**STUDENT HANDOUT**

**NO. 302**

**SUMMARY  
PROGRESS CHECK  
AND JOB PROGRAM**

**FOR MODULE 30-2**

**JUNE 1984**

SUMMARY  
LESSON TWO

Transistor, Voltage and Current Regulators

This lesson covers circuits which are designed to regulate and maintain a constant voltage and current output and are called either voltage or current regulators depending on their purpose. Many are designed to maintain voltage or current outputs within plus or minus ( $\pm$ ) 0.1 percent.

The two types of basic voltage regulators are series and shunt. The classification of the regulator depends on how it is connected in the total circuit. Series regulators are connected in series while the shunt type regulator is connected in parallel with the output load resistance. This is a basic concept that you should keep in mind as you complete this lesson.

A simple series type voltage regulator schematic is shown in Figure 1. Voltages are shown to help explain how the regulator works and enable you to understand the regulator's operation more readily.

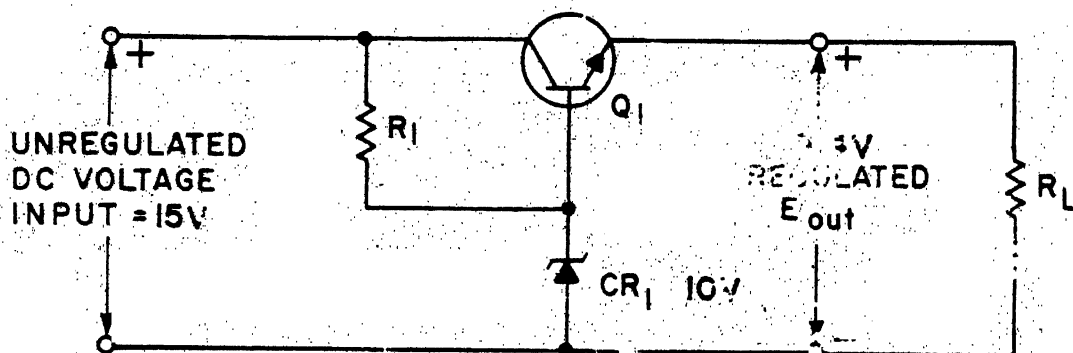


Figure 1

SERIES TYPE VOLTAGE REGULATOR

Q1 is used to regulate the voltage and functions in much the same way as a variable resistor would function. The main advantage of using the transistor is that it responds almost instantaneously to changes in input voltage or load current. The Zener diode CR1 blocks current flow until the applied voltage reaches or exceeds the Zener or break down voltage and provides a reference voltage for the base of Q1. Since Q1 is a series dropping device all current from the power supply flows through it. Q1 compensates for increases and decreases in input voltage and load current by changing its forward bias and resistance. With a 15 volt input voltage and a 10 volt Zener voltage, the regulated DC output is 9.4 volts. This results in a 0.6 volt voltage drop between the base and emitter of Q1.

Momentary increases or decreases in input voltage result in momentary changes in output voltage.  $Q_1$  compensates by increasing or decreasing its resistance, and the voltage drop changes in accordance with the amount of the transistors forward bias. In this way the transistor maintains a constant output voltage.

Again refer to the schematic. When the load current changes there is a change in voltage drop across  $R_L$ . This results in a change in the voltage drop across  $Q_1$  and the transistor compensates for changes in load current in much the same way that it compensates for changes in input voltage. Before proceeding further make sure you understand how the circuit shown compensates for increases and decreases in input voltage and load current.

The schematic for a shunt type voltage regulator is shown in Figure 2. Except for the addition of resistor  $R_s$  the components of this circuit are identical with those of the series regulator. The other difference is the regulating device is connected in parallel with the load resistance. Note that the series dropping resistor  $R_s$  is connected in series with the load resistance and that  $CR_1$  and limiting resistor  $R_1$  function as a voltage divider to provide a constant DC potential to the base-collector of  $Q_1$ .

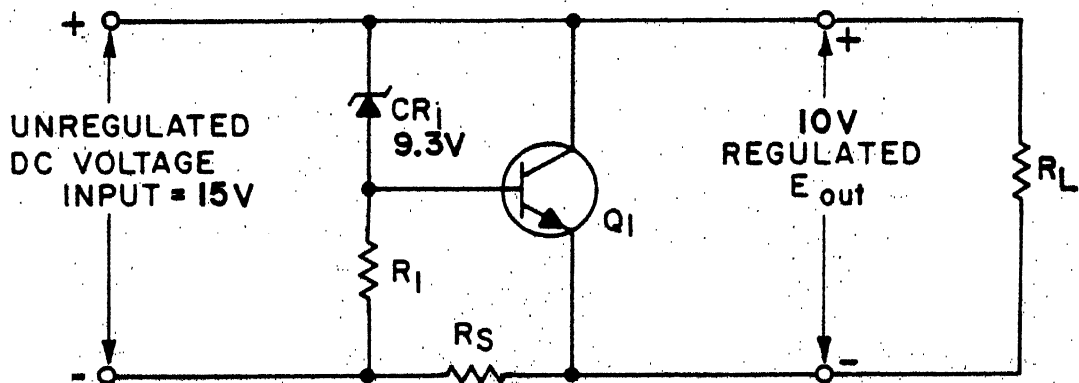


Figure 2

SHUNT TYPE VOLTAGE REGULATOR

With a 10 volt output voltage and Zener voltage of 9.3 volts the voltage drop across  $R_1$  is 5.7 volts as long as the circuit is providing a 15 volt input.  $R_s$  is the key component of this circuit because  $CR_1$  and  $R_1$  are connected in parallel with the load and any change in voltage is also reflected across  $R_1$ . Any change in voltage drop across  $R_1$  results in a change in the forward bias of  $Q_1$  and therefore a change in the amount of current that is allowed to flow through the transistor. A good technique to help you understand and remember how the regulator compensates for changes in voltage is to substitute values that are different from those shown on the schematic and make the necessary mathematic computations.

Changes in load current are compensated for by  $R_s$  and  $Q_1$ . For example, an increased load current results in an increased voltage drop across the series dropping resistor  $R_s$ . This action reduces the forward bias for  $Q_1$ .  $Q_1$  compensates by increasing its resistance thereby reducing the amount of current that flows through it. Since less current flows through the transistor more current is allowed to flow through the load resistance. This returns the voltage drop across  $R_s$  to its former state. The components operate in the opposite way when the load current decreases.

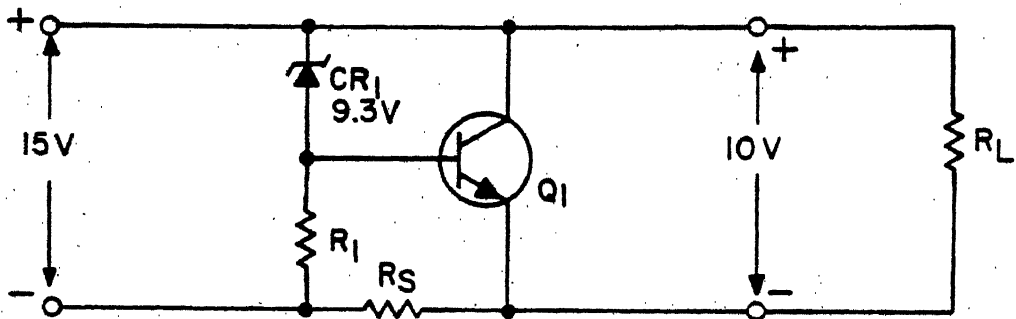


Figure 2

## SHUNT TYPE VOLTAGE REGULATOR

A voltage comparator provides more precise regulation. The schematic for a typical comparator is shown in Figure 3.

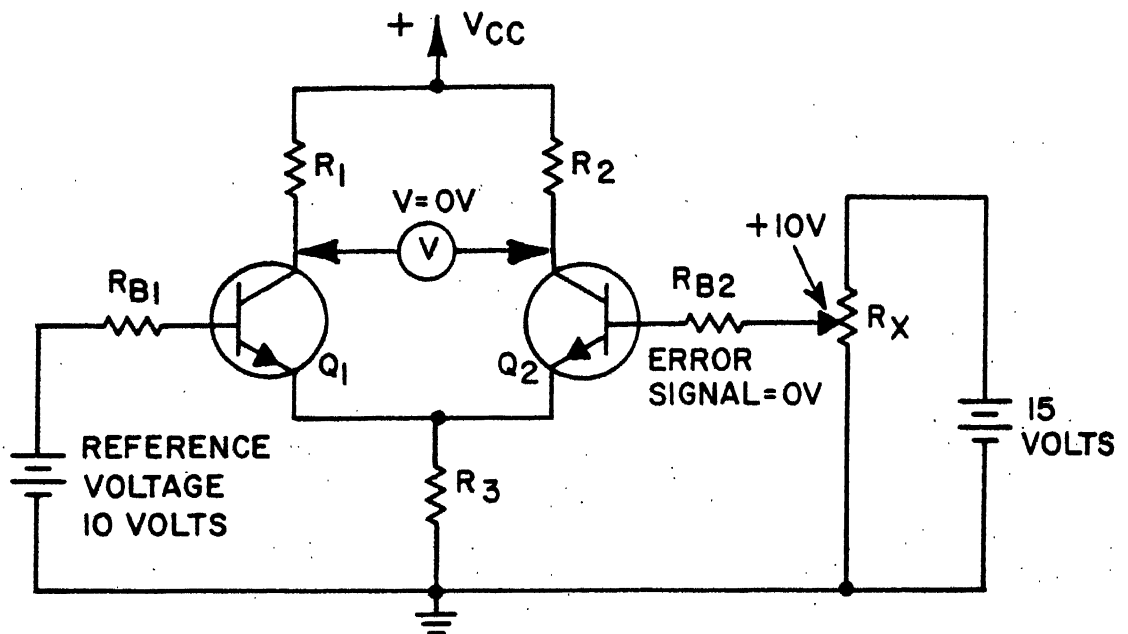


Figure 3

## VOLTAGE COMPARATOR

The voltage comparator is sometimes called a differential amplifier because it amplifies the difference between the inputs to  $Q_1$  and  $Q_2$ . These transistors are identical and load resistors  $R_1$  and  $R_2$  are also identical. So long as the voltage applied to the base of both transistors is equal the circuit remains balanced and has no output. The comparator functions because the collector voltages of the transistors are  $180^\circ$  out of phase with each other. In other words when the collector voltage of  $Q_2$  is more positive, the collector voltage of  $Q_1$  is less positive.

Figure 4 is the schematic of a circuit which you will encounter quite frequently and is called a Darlington type amplifier.

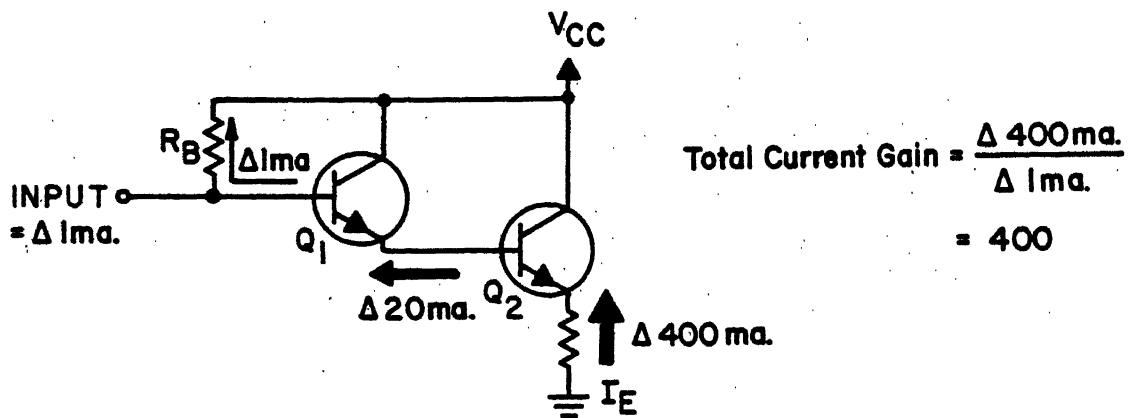


Figure 4

#### DARLINGTON AMPLIFIER

The advantage of the Darlington amplifier is high input impedance and high gain. The Greek letter Delta, which is represented by an equilateral triangle, is used to designate "a change of." Notice that the emitter output current of one transistor is the base current for the other transistor. This type of circuitry results in a current gain which is the product of the current gains in the individual transistors. In the example shown both transistors have a gain of 20. Therefore a 1 milliamper change at the base of Q1 will result in a total current output of 400 milliamperes. The possible combinations, of course, are endless.

The schematic shown in Figure 5 combines a voltage comparator and Darlington type amplifier.

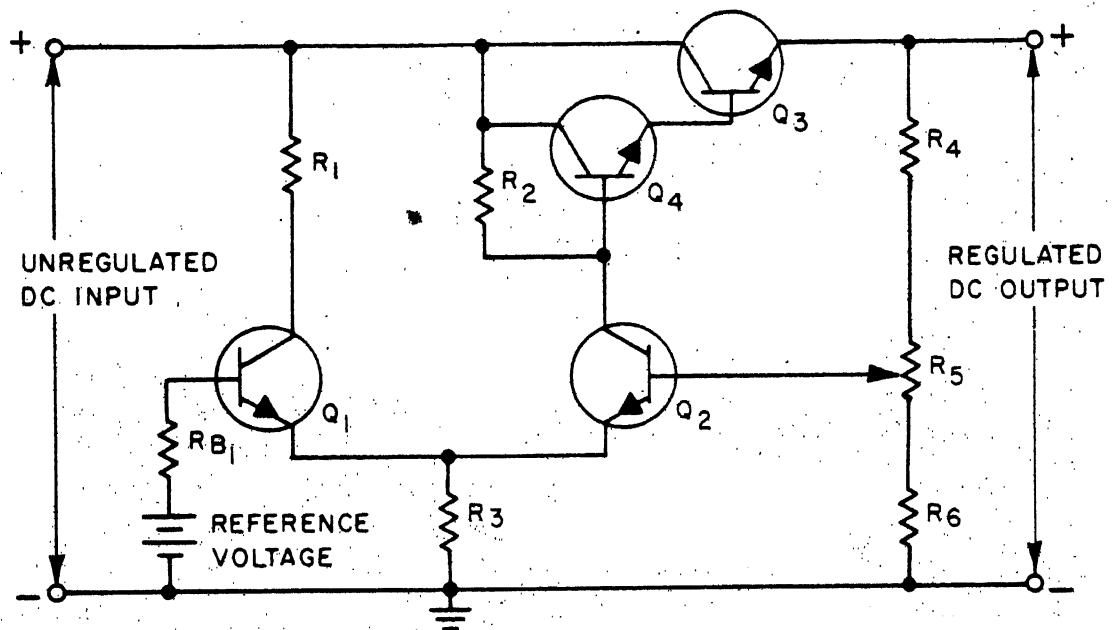


Figure 5

### DARLINGTON AMPLIFIER + VOLTAGE COMPARATOR

Study the schematic to make sure you understand how the two circuits work together to maintain a regulated DC output. If you have difficulty understanding how these two circuits work together, you may wish to view the tape slide presentation for this lesson or study the programmed instruction or narrative form of this lesson.

Sometimes it is necessary to regulate current output. Circuits which are used to regulate current output are called current regulators. The schematic for a simple current regulator is shown in Figure 6. In many respects this circuit is identical with that of a series voltage regulator. The main difference is that an additional component has been added. This component,  $R_1$ , is connected in series with the transistor and senses current changes.

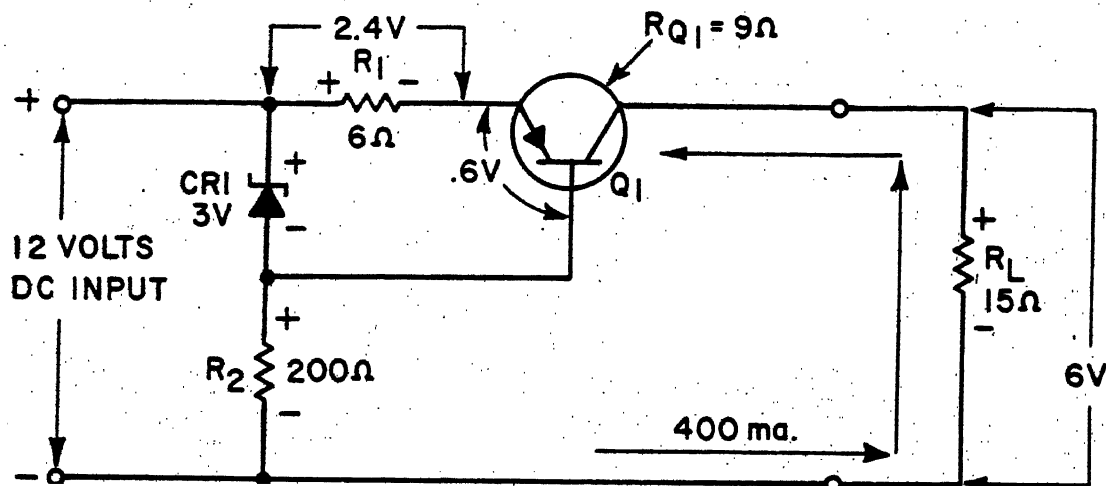


Figure 6  
CURRENT REGULATOR

Voltages are shown on the schematic to help you understand how the current regulator operates. Study the schematic and note that the bias of  $Q_1$  is the difference between the voltages across Zener diode  $CR_1$  and  $R_1$ . Since these components have opposite polarities the bias of the transistor is the difference between the two voltages.

Changes in the circuit load resistance causes a corresponding increase or decrease in current flow through the regulating device. Changes in load resistance are offset by corresponding changes in the transistor resistance. For example, a 5 ohm increase in the transistor resistance is the result of a 5 ohm decrease in the load resistance. Because the circuit is a current regulator the current remains constant. However, regulating the current in this way results in changes in the output voltage.

The schematic shown in Figure 7 is a current limiter. This type of circuit is used to prevent damage to delicate circuits which use semiconductor devices.



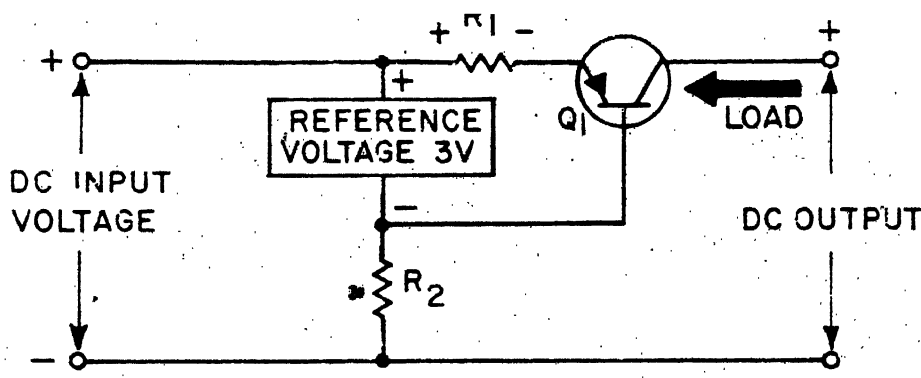


Figure 7

## CURRENT LIMITER

Since the current limiter has a short response time it protects critical circuits against current overload. Notice that the schematic is identical with the schematic for the current regulator. The only difference between a current regulator and current limiter is the size, or value, of the series dropping resistor. The resistor which is used in the current limiter is smaller than the resistor which is used in the regulator. In order for the limiter to operate, a reference voltage must be provided. This is shown in the schematic as a box. If you are unable to recall how circuits provide reference voltages refer to other parts of this lesson, the narrative, programmed instruction, or audio visual materials.

Changes in the transistor's bias and resistance compensate for changes in load current. Make sure you understand the basic operation of the limiter before proceeding further.

You should now be familiar with circuits which are used to regulate and control voltage and current outputs. As you complete the job program for this lesson you work with the NIDA model 201 power supply trainer. The circuits which are used in this trainer combine all the regulation circuits you have studied. When you become familiar with the NIDA equipment you will better understand how regulator devices operate together to accomplish complete regulation.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE 30-2A ADDENDUM. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK  
LESSON 2Transistor, Voltage and Current Regulators

1. Circuits which maintain a constant voltage or current are called \_\_\_\_\_.
- regulators
  - multipliers
  - filters
  - controllers

REFER TO FIGURE 1 BELOW WHEN ANSWERING QUESTIONS 2 AND 3.

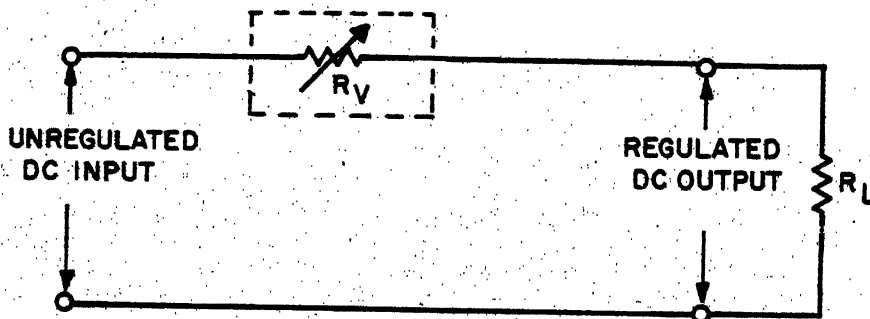


Figure 1

SERIES REGULATOR

2. If the input voltage decreases, what must be done to the value of  $R_v$  in order to bring the output voltage back to normal?
- Increase
  - Decrease
  - Remain the same
3. If the load current decreases, the reason for this decreased load current is a/an
- increased input voltage
  - decreased  $R_v$
  - increased  $R_L$
  - decreased  $R_L$

4. Decreasing the resistance of  $R_V$  will compensate for a/an

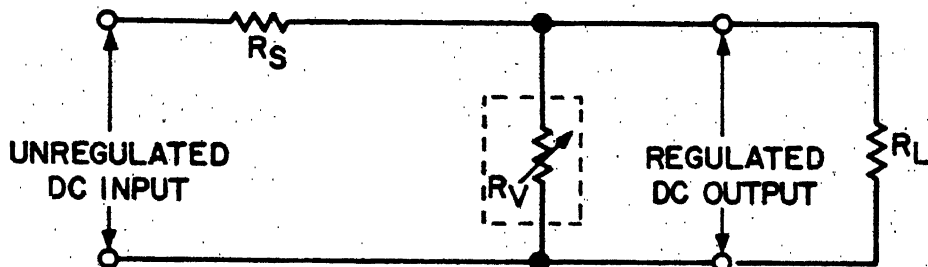


Figure 2

## SHUNT VOLTAGE REGULATOR

- increased input voltage or an increase in load current.
- increased input voltage or a decrease in load current.
- decreased input voltage or an increase in load current.
- decreased input voltage or a decrease in load current.

REFER TO FIGURE 3 WHEN ANSWERING QUESTIONS 5 AND 6.

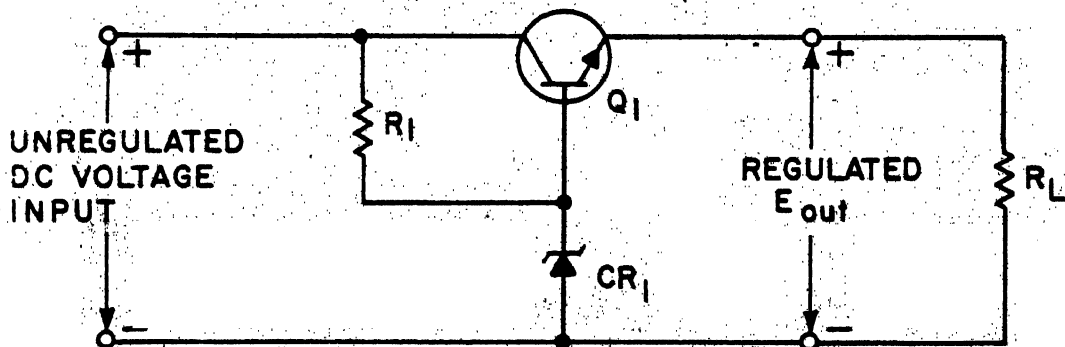


Figure 3

## SERIES TRANSISTOR VOLTAGE REGULATOR

- If the load current decreases, the value of the emitter voltage before regulation will
  - increase.
  - decrease.
  - remain the same.
- If the input voltage increases, the
  - voltage across  $CR_1$  will decrease.
  - impedance of  $Q_1$  increases.
  - output impedance of  $R_L$  will increase.
  - voltage across the base-collector junction decreases.

REFER TO FIGURE 4 BELOW WHEN ANSWERING QUESTIONS 7 AND 8.

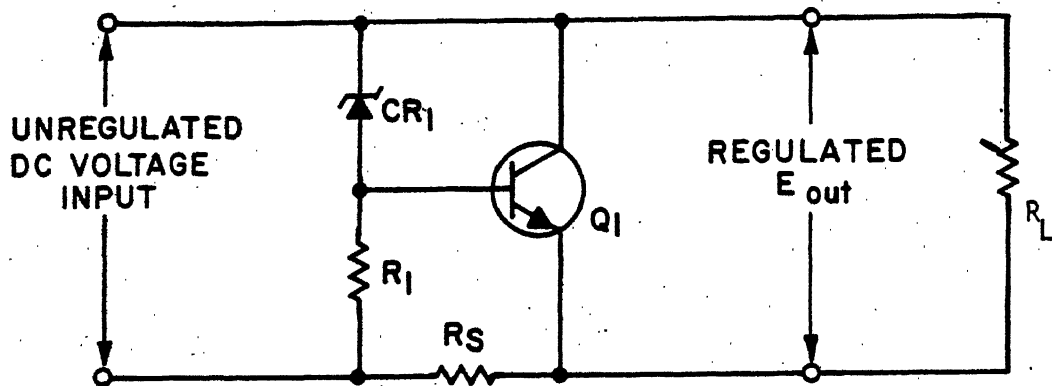


Figure 4

SHUNT TRANSISTOR VOLTAGE REGULATOR

7. The purpose of Zener diode CR1 is to maintain a constant
  - a. collector-base voltage.
  - b. regulated output voltage.
  - c. emitter-base voltage.
  - d. voltage across R1.
8. If the current flowing through RL increases because RL decreases,
  - a. the voltage across RS will decrease.
  - b. transistor current will decrease.
  - c. base-emitter voltage will increase.
  - d. the voltage across CR1 will decrease.
9. The electronic circuit which makes better voltage regulation possible is called a
  - a. series regulator.
  - b. voltage doubler.
  - c. shunt regulator.
  - d. voltage comparator.

REFER TO FIGURE 5 BELOW WHEN ANSWERING QUESTIONS 10 AND 11.

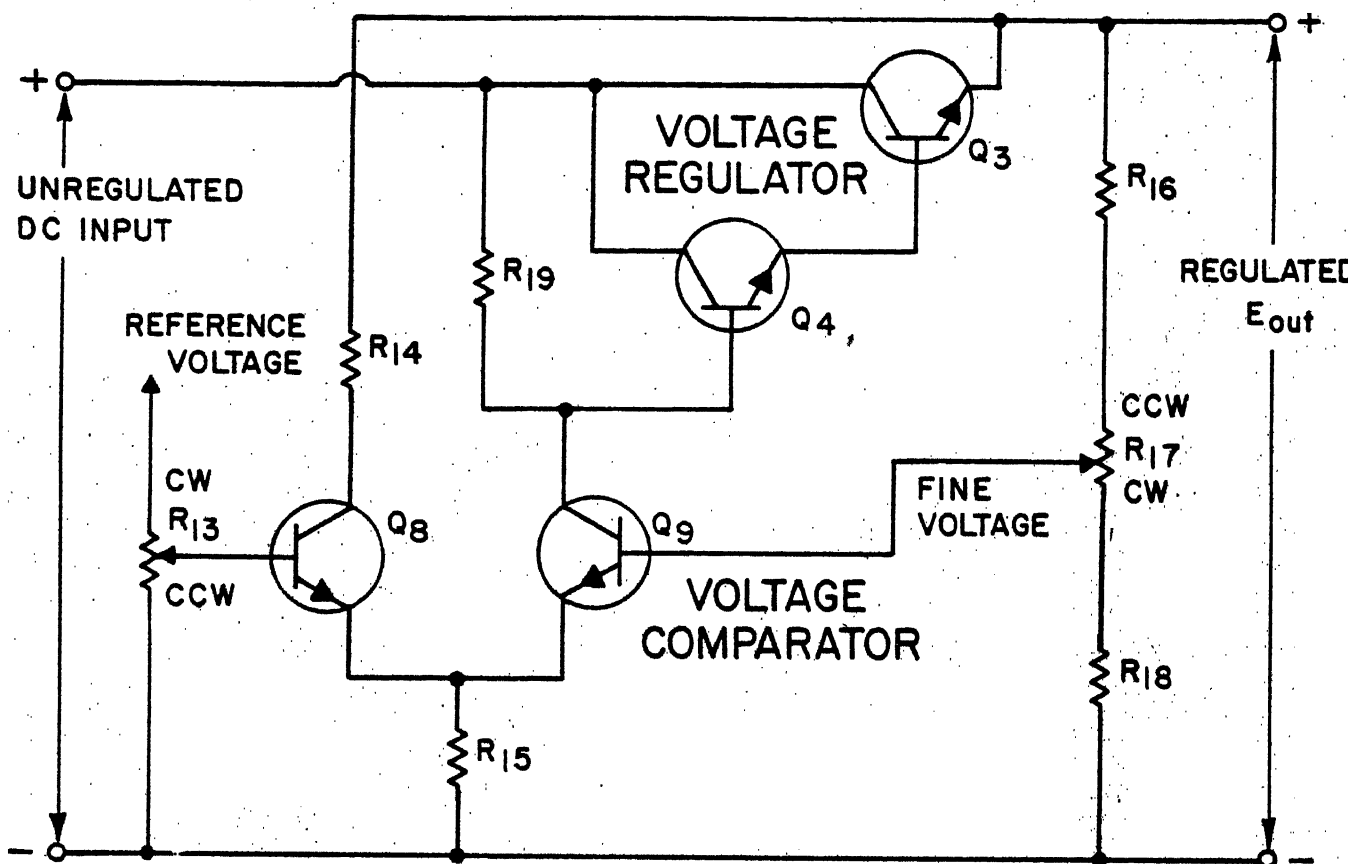


Figure 5

### SHUNT DETECTED SERIES VOLTAGE REGULATOR

10. Any change in voltage from the collector of  $Q_9$  applied to the base of  $Q_4$  is known as the \_\_\_\_\_ signal.
  - a. reference
  - b. error
  - c. applied
  - d. correction
11. If the fine voltage control  $R_{17}$  is turned in a CCW direction, the
  - a. base voltage of  $Q_4$  will increase.
  - b. base-emitter voltage of  $Q_9$  will increase.
  - c. regulated output voltage will increase.
  - d. regulation ability of  $Q_3$  and  $Q_4$  will be exceeded.

12. A differential amplifier produces signals that are \_\_\_\_\_ (equal/unequal) in amplitude and \_\_\_\_\_ (in phase/out of phase) with each other.
- equal, in phase
  - unequal, in phase
  - equal, out-of-phase
  - unequal, out-of-phase

REFER TO FIGURE 6 BELOW WHEN ANSWERING QUESTIONS 13 AND 14

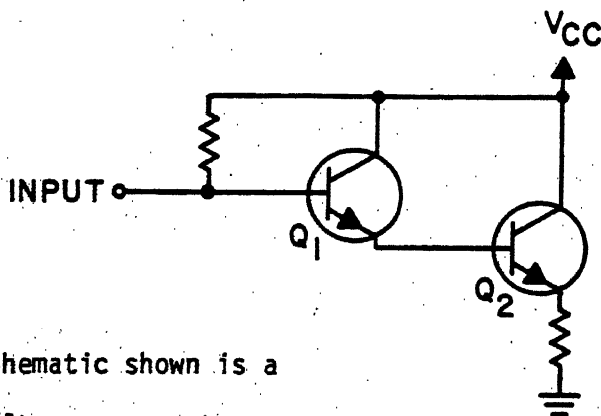


Figure 6

13. The schematic shown is a
- voltage comparator.
  - shunt type series regulator.
  - voltage doubler.
  - Darlington amplifier.
14. If transistors Q1 and Q2 have gains of 20 and 30 respectively, what is the change in emitter current of Q2 assuming of a 2 milliamperes input change at the base of Q1?
- 50 mA.
  - 100 mA.
  - 600 mA.
  - 1200 mA.
15. The output gain of a Darlington type amplifier is the \_\_\_\_\_ of the gain of the transistors which make up the amplifier.
- ratio
  - sum
  - difference
  - product
16. Darlington amplifier circuit configuration requires that the \_\_\_\_\_ of one transistor must be connected to the \_\_\_\_\_ of the other transistor.
- base, collector
  - collector, emitter
  - emitter, base
  - base, base

REFER TO FIGURE 7 WHEN ANSWERING QUESTIONS 17 AND 18.

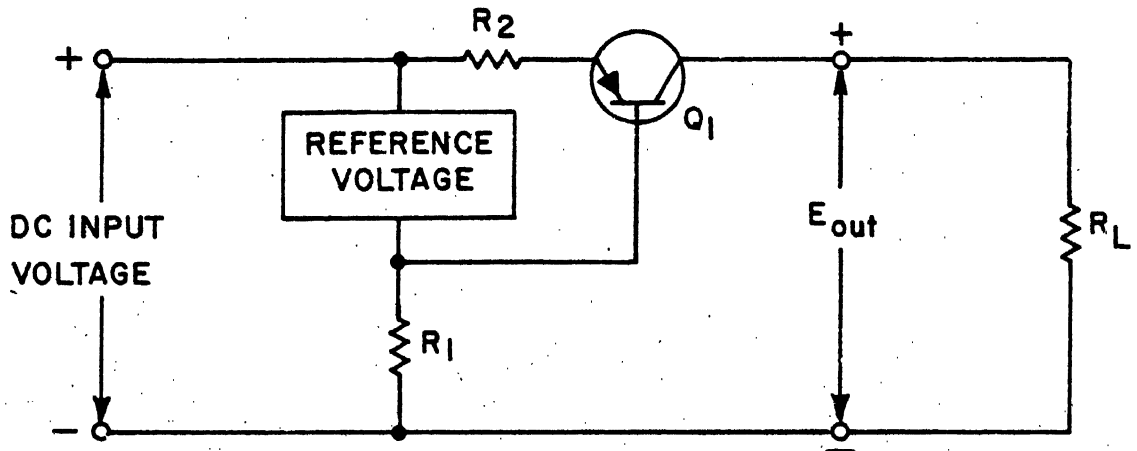


Figure 7

### CURRENT LIMITER

17. The purpose of this circuit is to protect the equipment from
  - a. shorted components.
  - b. open circuited components.
  - c. excessive current.
  - d. excessive load impedances.
18. If the load current decreases, the voltage across  $R_2$  will
  - a. increase.
  - b. decrease.
  - c. remain the same.
19. Refer to the schematic diagram of the 201 power supply. The collector load impedance for  $Q_9$  is
  - a.  $Q_6$  and its associated circuitry.
  - b.  $Q_4$  of the series voltage regulator.
  - c. the differential amplifier  $Q_8$  and  $Q_9$ .
  - d. series voltage regulator  $Q_7$  and  $CR_5$ .

- 20 . Refer to the schematic diagram of the 201 power supply. If the current through Q9 increases, the resultant current through Q6 will
- a. increase.
  - b. decrease.
  - c. remain the same.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY PROCEED TO THE JOB PROGRAM. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.



JOB PROGRAM  
FOR  
LESSON II

Transistor Voltage And Current Regulators

INTRODUCTION

This Job Program will demonstrate the various transistor voltage regulators and their operation. It is designed to permit you to prove to yourself the principles you studied on voltage regulators. Since the input voltage cannot be varied because this voltage is applied to the equipment from a receptacle, the Job Program will be oriented toward changes in load.

SAFETY PRECAUTIONS:

Observe all standard safety precautions. Beware of all open and bare connections; an energized circuit may have dangerous voltages present. When connecting the digital multimeter to components, take care not to short probes to bare connections on the printed circuit board. Be EXTREMELY CAREFUL when measuring voltages on the emitter, base, and collector of transistors; it is very easy to short these elements to the case of transistors which may very easily damage these transistors.

EQUIPMENT AND MATERIALS

1. NIDA 201 Power Supply
2. PC 201 Printed Circuit Board
3. NIDA 201L Load Box
4. Dual Banana Plug Cable
5. Digital Multimeter and Test Leads
6. NIDA 201 Power Supply Instruction Manual
7. NIDA 201 Schematic Diagram (Fold Out P.P. 83-84)

PROCEDURES: CHECK OUTPUT VOLTAGE OF DMM TO ENSURE SAFE LIMITS  
FOR TRANSISTOR JUNCTION.

NOTE: STEPS 1 THROUGH 7 WILL SET UP THE NIDA 201 POWER SUPPLY FOR NORMAL OPERATION INTO A DUMMY LOAD. REFER TO THE SCHEMATIC DIAGRAM OF THE NIDA 201 POWER SUPPLY (FOLDOUT P.P. 83-84).

1. Turn all front panel controls CCW.
2. Remove the top cover from NIDA 201 Power Supply.
3. Install the NIDA 201 printed circuit board in the Power Supply.
4. Connect one end of the dual banana plug cable to the NIDA 201 Power Supply output jacks, observing the proper polarity (the tab on the side of the plug to the ground connection). Connect the other end of the plug to the NIDA 201L load box again observing the proper polarity.
5. Set the load selector switch on the NIDA 201L load box to variable with the variable load set to "minimum load", and place the toggle switches for load 1, 2, and 3 to the up position with the series-parallel switch in the parallel position.
6. Plug in and energize the NIDA 201 Power Supply.
7. Rotate the coarse voltage control R13 and the fine voltage control R17 fully CW. Rotate the current control R5 fully CCW.

NOTE: STEPS 8 THROUGH 11 WILL SET THE CURRENT LIMITING VALUE FOR THE NIDA 201 POWER SUPPLY IN THIS JOB PROGRAM.

8. Turn variable load control on the NIDA 201L load box to maximum.
9. Push limit switch in and set current control R5 on the front panel to 1.0 A.
10. Release the current limit switch. You have now established the maximum amount of current that can flow in the circuit. DO NOT adjust this control anymore during this part of the Job Program.
11. Observe and record the front panel current and voltage from the front panel meters. \_\_\_\_\_ Amps \_\_\_\_\_ VDC

NOTE: STEPS 12 THROUGH 14 WILL ESTABLISH THE REGULATED VOLTAGE RANGE FOR THE NIDA 201 POWER SUPPLY.

12. Very slowly rotate the variable load control on the NIDA 201L load box CCW.
  - a. Is the voltmeter indication increasing/decreasing/or remaining the same?  
\_\_\_\_\_
  - b. Is the voltage regulated or unregulated at this time? \_\_\_\_\_

13. Continue rotating the variable load control on the NIDA 201L load box CCW until the voltmeter indicates a steady voltage. Observe and record this voltage and current.

\_\_\_\_\_ VDC. \_\_\_\_\_ Amps.

14. Rotate the variable load control on the 201L load box to minimum.

a. What has happened to the voltmeter indication?

- (1) increased
- (2) decreased
- (3) remained the same

b. What has happened to the ammeter indication?

- (1) increased
- (2) decreased
- (3) remained the same

c. What is the indication on the ammeter? \_\_\_\_\_ A.

d. Is the voltage being regulated at this time? \_\_\_\_\_ Yes/No

e. What is the current range over which voltage regulation is taking place?

\_\_\_\_\_ A.

15. Set the coarse voltage control (R 13) to 15 VDC output on the front panel voltmeter.

16. Rotate the variable load control on the NIDA 201L load box for an indication of 0.6 A on the front panel ammeter. DO NOT touch the controls on the power supply for the remainder of this part of the Job Program.

NOTE: You will now analyze the operation of the series voltage regulator consisting of Q7, CR5, R13 and the associated circuitry. You will notice that when you decrease the load, less current is required from the power supply and that when you increase the load, more current is required from the power supply. You will prove that within limits the series voltage regulator will maintain the voltage across R13 and the output voltage from the power supply constant over a wide variation in load.

17. Plug in and energize the digital multimeter. Connect the common probe to pin #1 of printed circuit board 201PC using an alligator clip.

18. Measure and record the voltages present on the designated elements of Q7.

V<sub>C</sub> = \_\_\_\_\_ V<sub>L</sub>  
V<sub>B</sub> = \_\_\_\_\_ VDC  
V<sub>E</sub> = \_\_\_\_\_ VDC

19. Using the measurements you obtained in step 18, calculate the base-emitter voltage of Q7 \_\_\_\_\_ VDC.
20. Increase the variable load control on the NIDA 201L load box until the front panel ammeter indicates 0.8 amperes.

21. Measure and record the voltages present on the designated elements of Q7.

$V_C$  = \_\_\_\_\_ VDC  
 $V_B$  = \_\_\_\_\_ VDC  
 $V_E$  = \_\_\_\_\_ VDC

22. Using the measurements you obtained in steps 21, calculate the base-emitter voltage of Q7 \_\_\_\_\_ VDC.
23. Decrease the variable load control on the NIDA 201L load box until the front panel ammeter indicates 0.2 amperes.

24. Measure and record the voltages present on the designated elements of Q7.

$V_C$  = \_\_\_\_\_ VDC  
 $V_B$  = \_\_\_\_\_ VDC  
 $V_E$  = \_\_\_\_\_ VDC

25. Using the measurements you obtained in step 24, calculate the base-emitter voltage of Q7 \_\_\_\_\_ VDC.

- a. What is the difference in the base-emitter voltages measured in steps 19, 22 and 25? \_\_\_\_\_ VDC.
- b. What happened to the output voltage on the front panel voltmeter?  
(increased/decreased/remained the same).  
\_\_\_\_\_

NOTE: You have now completed the evaluation of a series voltage regulator by increasing and decreasing the load. If, at this time, you do not understand what you have done, go back over this Job Program of the series voltage regulator until you thoroughly understand it.

The next circuit you will analyze is the differential amplifier. Since the inputs and outputs of this amplifier are not equal, it is not a true differential amplifier but a modified version. Looking at the schematic diagram you will notice that coarse voltage control R13 varies the base voltage of Q8. Notice that fine voltage control R17 varies the base voltage of Q9, whose output is applied to the base of Q4 and the collector of Q6.

The front panel fine voltage control R17 and the coarse voltage control R13 on the front panel are not external controls in actual equipment. You will be required, in the equipment phase of this school and in the fleet, to measure and adjust these voltages for proper regulated indications. If not adjusted properly, they cause problems in both radar and communications systems.

26. Set the front panel controls the same as you did in steps 7 through 10 of this Job Program.
- 26a. Set the load control on the NIDA 201L load box to minimum.
27. Set the coarse voltage control R13 to indicate 15 VDC on the front panel voltmeter.
28. Reset the variable load control on the 201L load box to indicate 0.6 amperes on the front panel ammeter.
29. If the load increases, the impedance of Q3 and Q4 should decrease and the voltage across this impedance should decrease. Using the digital multimeter what is the present indication at pin #15? \_\_\_\_\_ VDC. What is the indication on the front panel ammeter? \_\_\_\_\_ A. What is the indication on the front panel voltmeter? \_\_\_\_\_ VDC. What is the difference between the voltage at pin #15 and the front panel voltmeter? (This voltage is  $V_{CE}$  for Q3).
30. Insert the probe of the digital multimeter into pin #15 and increase the load to 0.8 amperes.
- What is the digital multimeter indication? \_\_\_\_\_ VDC.
  - What is the front panel voltmeter indication? \_\_\_\_\_ VDC.
  - What is the difference between steps 30a and 30b? \_\_\_\_\_ VDC. (This voltage is  $V_{CE}$  for Q3)
  - What is the difference between  $V_{CE}$  in Step 29 and Step 30c?
  - What happened to the impedance of Q3 when the load increased? (increased/decreased/remained the same).
  - Does this prove the statement in step 29? \_\_\_\_\_ (Yes/No).
31. Leave the probe in pin #15 and decrease the load to 0.2 amperes.
- What is the digital multimeter indication? \_\_\_\_\_ VDC.
  - What is the front panel voltmeter indication? \_\_\_\_\_ VDC.
  - What is the difference between step 31a and 31b? \_\_\_\_\_ VDC.
  - From the information obtained above, is the series voltage regulator operating properly? \_\_\_\_\_ (Yes/No).

NOTE: You have completed your analysis of the modified differential amplifier and series voltage regulator Q3 and Q4 and determined that the circuits are operating properly. You did not see a difference in the output voltage on the front panel voltmeter because the error signal applied to the base of Q9 and the correction signal applied to the base of Q4 happen so fast that a voltmeter cannot detect the change. If you do not understand what you

have done, go back over this part of the Job Program until you understand it.

The next circuit you will analyze is the current regulator Q6. You will prove that the current through Q6 will remain constant from minimum load to 0.8 amperes because the base-emitter voltage remained constant. Reviewing back to transistor theory you may remember that the base-emitter voltage controls the amount of current flow through a transistor and if this voltage remains constant then the current will be constant. THIS WILL BE YOUR PROOF.

32. Set variable load control on the NIDA 201L load box to minimum. Measure and record the voltages present on the designated elements of Q6.

$V_C$  = \_\_\_\_\_ VDC.  
 $V_B$  = \_\_\_\_\_ VDC.  
 $V_E$  = \_\_\_\_\_ VDC.

33. Set variable load control on the NIDA 201L load box to 0.8 amperes. Measure and record the voltages present on the designated elements of Q6.

$V_C$  = \_\_\_\_\_ VDC.  
 $V_B$  = \_\_\_\_\_ VDC.  
 $V_E$  = \_\_\_\_\_ VDC.

34. What is the base-emitter voltage in step 32? \_\_\_\_\_ VDC.

35. What is the base-emitter voltage in step 33? \_\_\_\_\_ VDC.

36. What does the information in steps 34 and 35 tell you about the current through Q6 as the load was increased from minimum to 0.8 amperes? \_\_\_\_\_.

NOTE: So far, all the principles of voltage and current regulation you studied in the narrative, programmed instruction, summary, or tape/slide have been proven by you in this Job Program.

You will now analyze the operation of the current limiter consisting of Q1, Q2, R2, and R3. The purpose of this limiter is to protect the power supply from excessive currents.

37. Set the variable load control on the NIDA 201L load box to minimum.

38. Set all controls on the front panel of the power supply fully CW except current control (R5) which should be set fully CCW.

39. Set the variable load control on the NIDA 201L load box to maximum. Measure and record the voltages present at the indicated points in the circuit and calculate the voltage between the emitter of Q1 and the base of Q2.

R5 Set to ER2 (Pin 7 to left side R7) (Pin 13 to left side of R7)

CCW.	_____ VDC	_____ VDC	_____ VDC
0.3 A	_____ VDC	_____ VDC	_____ VDC
0.6 A	_____ VDC	_____ VDC	_____ VDC

a. Is limiting action taking place at each of the above settings? \_\_\_\_\_  
(Yes/No).

b. Are the transistors conducting with R5 fully CCW? (Yes/No).

c. Explain your answer to step 39b above. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

40. Return front panel current control R5 to its fully CCW position.

41. Very slowly rotate the front panel current control R5 CW until the ammeter just starts to indicate.

42. Measure and record the voltage between pin #12 and the base of Q2. \_\_\_\_\_  
VDC.

43. Is the current limiter operating properly at this time? \_\_\_\_\_ (Yes/No).

NOTE: You have completed your analysis of the current limiter. If you do not understand what you have done, go back over this part of the Job Program until you do understand it.

The last circuit you will analyze in this Job Program is the variable shunt voltage regulator. It is designed to be variable so that the voltage on the current limiter would vary as you changed the front panel current control R5 or as you changed the load. The important point to check here is that the output of the regulator will be held to within a 4 volt range depending upon the setting of R5.

44. Set the variable load control on the NIDA 201L load box to maximum, the front panel fine voltage control and the coarse voltage control fully CW.

45. Set front panel current control R5 fully CCW.

46. Measure and record the voltage from pin #7 to the left side of R7, which is the emitter of Q5 \_\_\_\_\_ VDC.

CAUTION: DO NOT LEAVE R5 IN FULLY CW POSITION ANY LONGER THAN 20 SECONDS.

47. Set front panel current control R5 fully CW.

48. Measure and record the voltage from pin #7 to the left side of R7 on the PCB which is the emitter of Q5 \_\_\_\_\_ VDC.

a. What is the maximum voltage change across Q5? \_\_\_\_\_ VDC.

- b. At what setting of R5 was the current through Q5 maximum? \_\_\_\_\_  
(CW/CCW).
- c. At what setting of R5 was the current through Q5 minimum? \_\_\_\_\_  
(CW/CCW).

CHECK YOUR RESPONSES TO THIS JOB PROGRAM WITH THE ANSWER SHEET. IF YOUR RESPONSES AGREE WITH THE ANSWER SHEET, YOU MAY TAKE THE LESSON TEST. IF YOUR RESPONSES DO NOT AGREE OR IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THIS JOB PROGRAM, REVIEW THE PROCEDURES OF THIS JOB PROGRAM, ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS, OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOUR RESPONSES DO AGREE.



INFORMATION SHEET  
LESSON 2Semiconductor TroubleshootingTRANSISTOR TROUBLESHOOTING

This information sheet is another in the series, and will help you to analyze data about a troubleshooting problem. This material is designed to remind you about significant relationships concerning transistors. These proven aids will aid you in arriving at a logical conclusion.

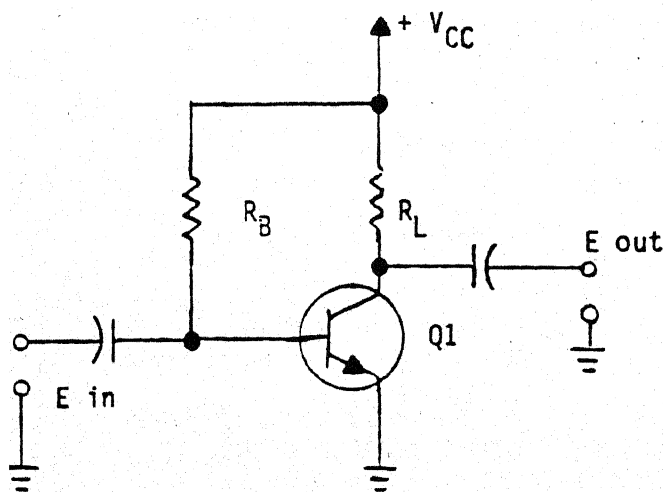
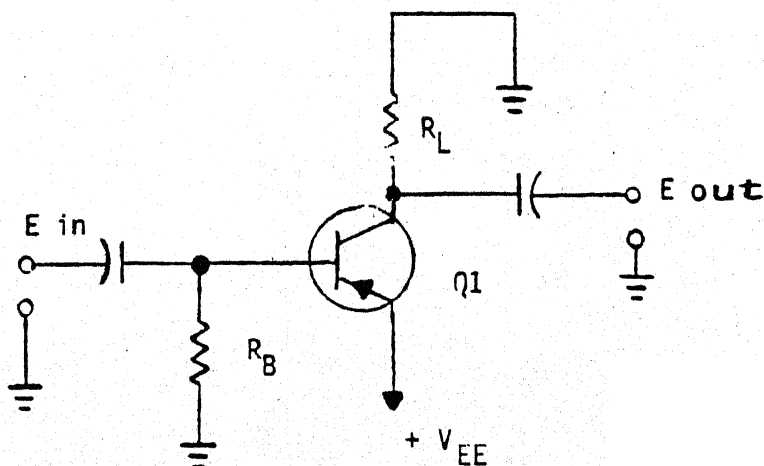
1. The voltages measured on individual elements of a transistor when a trouble occurs will primarily depend upon (1), the type of transistor (PNP or NPN) and (2), to what element the source voltage is applied, (emitter or collector).
2. Transistors may develop open or shorted junctions. It is quite difficult to open a transistor junction although in some cases, this will happen.
3. High power transistors rarely become leaky. In most cases they completely short, emitter to collector.
4. Low power transistors rarely completely short. They become leaky. Distortion occurs in the output.
5. If a coupling transformer, coil or tank capacitor should become detuned, for any reason, the output will be reduced and all DC voltages will be normal.
6. If a bypass capacitor should open, all DC voltages will be normal. The output may or may not be reduce in amplitude.
7. Open coupling capacitors will cause the output signal to be zero. All DC voltages will be normal.
8. An open emitter or cathode bypass capacitor will cause the output signal to decrease in amplitude (degeneration). All DC voltages will be normal.

NOTE: THE ABOVE STATEMENTS ARE GENERAL STATEMENTS AND APPLY TO ALL ELECTRONIC CIRCUITS. STATEMENTS #5, #6, #7 AND #8 ALSO APPLY TO VACUUM TUBE CIRCUITS.

9. When measuring voltages in a PNP transistor circuit with  $V_{CC}$  applied to the emitter, if  $V_C = V_E$  and is approximately equal to the source voltage, look for an open in the collector circuit. In an NPN transistor with the source voltage applied to the collector. If  $V_C = V_E$  and is very low, look for an open in the collector circuit. See attached schematic diagram.
10. If  $V_{CC} = 0V$ , look for an open in the power supply or battery circuit.

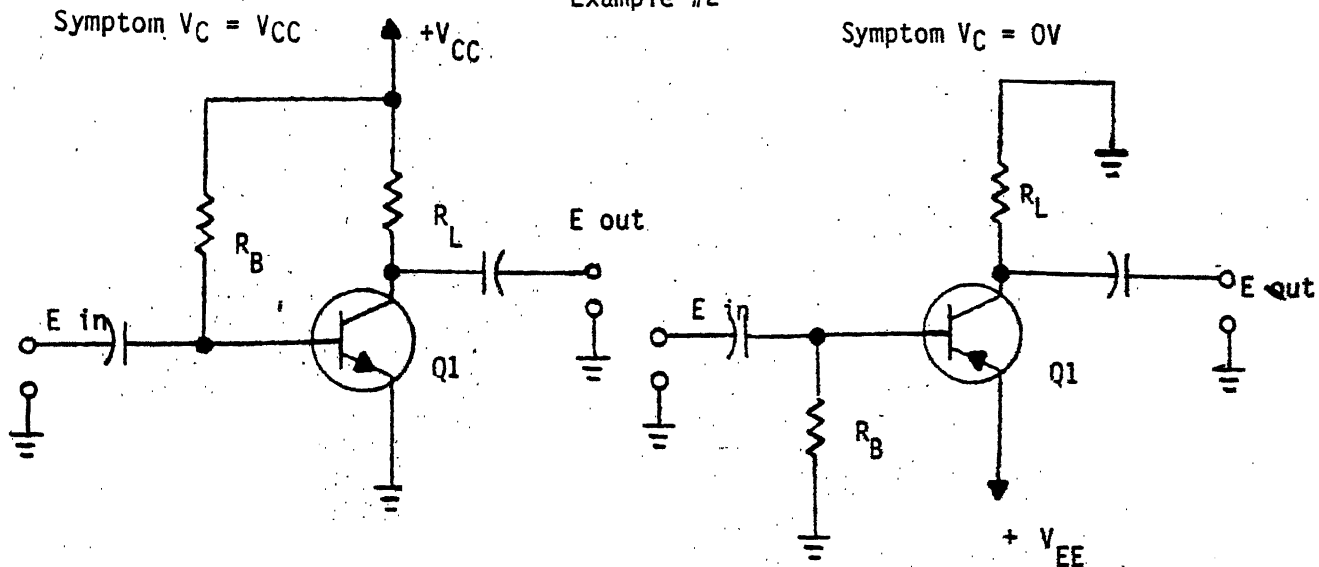
11. There are two conditions which would cause  $V_E$  to equal 0V, assuming that the emitter is not normally grounded by circuit design. An open B-E junction or an open base current limiting resistor. A shorted bias stabilizing resistor will also cause the above symptoms but this is very rare.
12. PNP-source applied to the emitter circuit with  $V_E$ ,  $V_B$  and  $V_C$  equal to 0V, look for an open emitter resistor. If the B-E junction were shorted  $V_C$  would not equal ZERO. NPN-source applied to the collector circuit.  $V_E$  is approximately equal to  $V_B$  and  $V_C = V_{CC}$  with  $V_E$  higher than normal, look for an open in the emitter circuit.
13. A leaky transistor will cause  $V_E$  to be higher than normal but  $V_C$  will not equal  $V_{CC}$  nor will  $V_C = 0V$  as in statement 12.
14. A Zero voltage reading on the base indicates trouble in the base circuit regardless of the voltages measured on the emitter or on the collector.

## Example #1

Symptom  $V_C = 0V$ Symptom  $V_C = V_E = V_{EE}$ 

Suspect: An open in the collector circuit or a shorted Q1, collector to emitter.

Confirm: Check Q1 and the collector circuit with an ohmmeter.



Suspect. An open transistor, (collector to emitter) or an open in the emitter circuit.

Confirm: Check Q1 and the emitter circuit with an ohmmeter.

### IN-CIRCUIT RESISTANCE MEASUREMENTS

The information presented here will help you to analyze the performance measurement data you obtain during the practice and performance tests in the course. This material concerns resistance measurements in circuits containing diodes and transistors. These devices produce measurements that must be carefully considered in order to detect faulty components.

### Diodes Resistance Measurements

A solid-state diode (PN junction) will indicate a low resistance when forward biased by the internal voltage source common to most ohmmeter circuits (some DVMs have probe voltages below the forward bias threshold, e.g., 30 mv). A high resistance is indicated on the ohmmeter when the diode is reverse biased. The ratio of high-to-low resistance should be greater than 10-to-1 in out-of-circuit measurements. However, in circuit resistance, measurements must consider possible parallel paths.

### Test 1

In Figure 1, with probe polarity as shown, diode CR2 is forward biased by the ohmmeter voltage source, while CR1 is reverse biased.

Ohmmeter  
Reading: 700 ohms

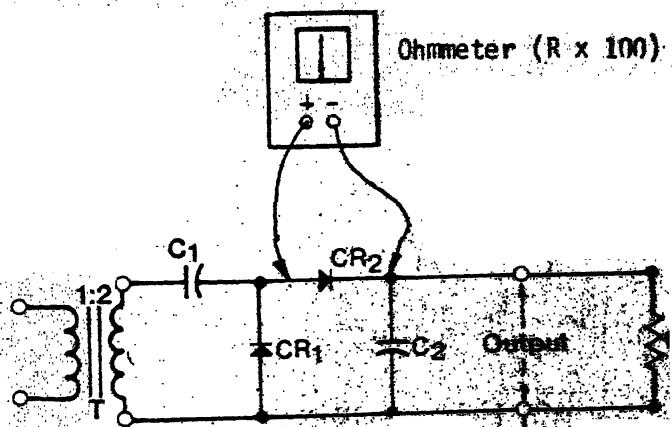


Figure 1

Test 2. Reverse the probes in Figure 1. Diode CR2 is now reverse biased, but CR1 is forward biased. A parallel path now exists consisting of CR1 and RL.

Ohmmeter

Reading: 2000 ohms.

Conclusion: CR2 is good. The low front-to back ratio across CR2 ( $\frac{2000}{700}$ ) is caused by the parallel path through CR1 when it is forward biased.

A similar condition would occur when measuring the resistance across CR1. Of course, the value of RL is a major factor in the ohmmeter reading.

### Transistor Measurements

A transistor is effectively two diodes connected back-to-back as shown in Figure 2.

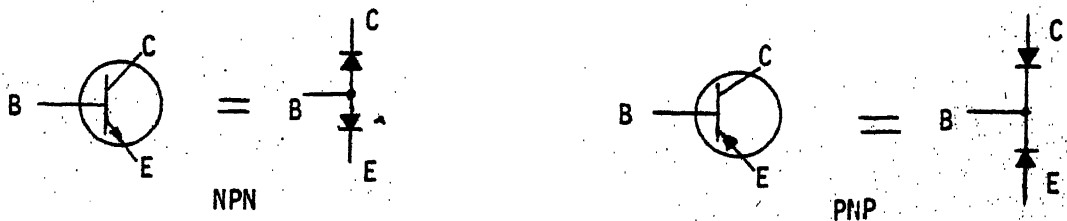


Figure 2

An ohmmeter will indicate low resistance when placed across a forward biased base-emitter or base-collector junction of a transistor. A high resistance will be indicated when the junction is reverse biased. The forward-reverse ratio should be greater than 10-to-1, just as in solid-state diode measurements, when out-of-circuit.

However, in-circuit measurements must consider parallel resistance paths.

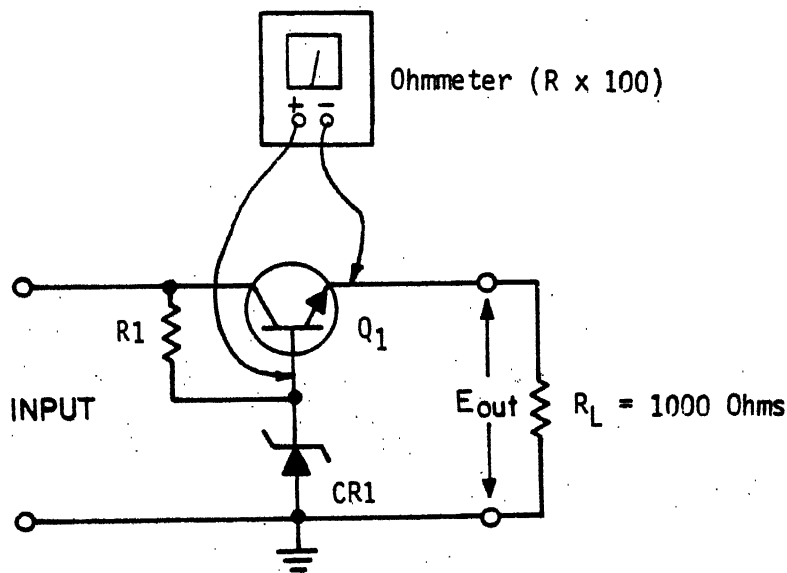


Figure 3

Test 1. In Figure 3, with the polarity of the probes as shown, the base emitter junction of  $Q_1$  is forward biased.  $CR_1$  is reverse biased.

Ohmmeter  
Reading: 850 ohms

Test 2. Reverse the probes of the ohmmeter. The base-emitter junction of  $Q_1$  is now reverse biased; however,  $CR_1$  is now forward biased, and with  $R_L$ , provides a parallel path across the base-emitter junction.

Ohmmeter  
Reading: 3000 ohms.

Conclusion. The base-emitter junction of  $Q_1$  is good.  $CR_1$  is forward biased by the ohmmeter which provides a parallel path, thus reducing the normal out-of-circuit 10-1 ratio.

$$\frac{3000}{850} = \frac{3.3}{1}$$

A similar condition would occur when measuring the base-collector junction because of  $R_L$ .

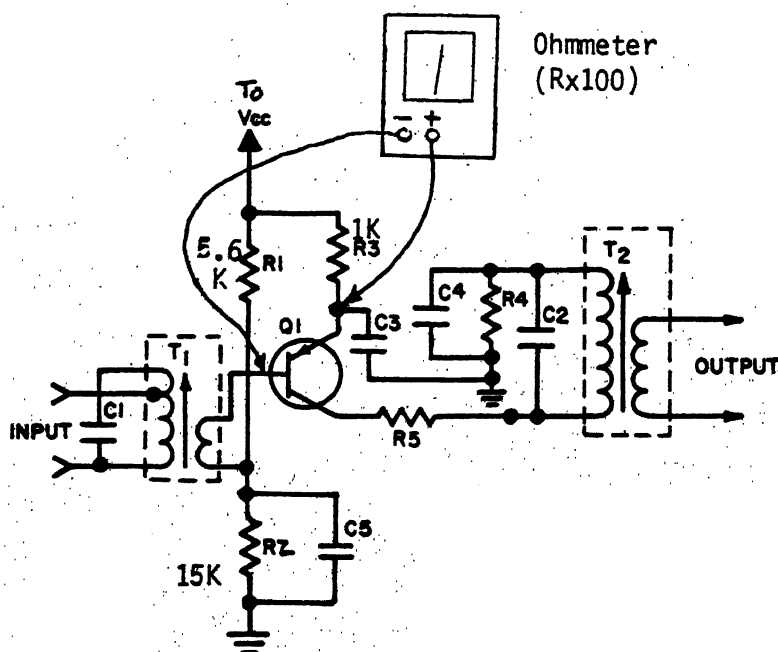


Figure 4

**Test 1.** In the circuit of Figure 4, the base-emitter junction of Q1 is forward biased by the ohmmeter. R1 and R3 parallel the junction, but are much larger than the junction resistance.

Ohmmeter  
Reading: 825 ohms

**Test 2.** Reverse the polarity of the ohmmeter probes. The base-emitter junction of Q1 is now reverse biased; but the parallel path of R1 and R3 now are a major factor.

Ohmmeter  
Reading: 6.6K ohms

**Conclusion:** The base-emitter junction of Q1 is good. The parallel resistance path of R1 and R3 reduces the ratio to  $\frac{6600}{825} = 8$

A similar condition would occur when measuring the base-collector junction of Q1. However in this case, the parallel path of R5, R2, R4 and the primary of T1 are over 16K ohms, thus proving a ratio greater than 10 to 1. (16K = about 10 to 1)

## FOR

## TROUBLESHOOTING PERFORMANCE TEST

## INTRODUCTION:

Using the following six step troubleshooting procedure will aid you in determining which component is faulty. In the split method of troubleshooting, Pin #15 has been selected as the starting point for dividing the circuit in half. If the voltage at Pin #15 is higher than normal or nearly normal chances are your problem is in one of the stages following Pin #15. If the voltage at Pin #15 is lower than normal, this tells you that a circuit prior to Pin #15 is dropping all the voltage. Since you are not permitted to unsolder components in order to make resistance measurements, it may be necessary, in some cases to remove the PCB from the power supply in order to remove parallel paths.

## EQUIPMENT:

1. NIDA 201 Power Supply
2. NIDA 201 Pre-faulted Circuit Board
3. Digital Multimeter
4. Simpson 260 Multimeter
5. 1 Pair of Multimeter Test Leads
6. NIDA 201L Load Box
7. Dual Banana Plug Cable

## INSTRUCTIONS:

1. Each student is required to determine the defective component in a prefaulted transistor regulator circuit board. Your six-step troubleshooting sheet must indicate you used accurate test measurements and a logical procedure to find the faulty component.
2. Standard test equipment will be available to you in the form of a digital multimeter and a Simpson 260 multimeter. You will be expected to observe all safety precautions throughout the test. Improper use of test equipment is considered a safety violation for each occurrence. A safety violation will result in an automatic failure of the performance test. In that event you will be counselled and given remedial training.

## TROUBLESHOOTING PERFORMANCE TEST

3. You will take a numbered position in the test room. After briefing by the Learning Center Instructor you will fill out the heading of the troubleshooting form. On a signal from the Learning Center Instructor you will start the test. If at any time during the test you should require assistance, raise your hand. DO NOT LEAVE YOUR POSITION. A Learning Center Instructor will assist you with your trouble.
4. If you do not understand these instructions, raise your hand and ask your Learning Center Instructor. If you do understand these instructions and upon a signal from your Learning Center Instructor you may now begin the Performance Test on the next page.

NOTE: You may remove the circuit board from the NIDA trainer to make resistance checks.



## FOR

## TROUBLESHOOTING PERFORMANCE TEST

DIRECTIONS: DO NOT WRITE IN THE PERFORMANCE TEST BOOKLET. MAKE ALL YOUR RESPONSES ON THE 6 STEP TROUBLESHOOTING SHEET SUPPLIED WITH THIS TEST PACKET. THIS PERFORMANCE TEST BOOKLET IS DESIGNED TO AID YOU IN COMPLETING THE STANDARD 6 STEP TROUBLESHOOTING FORM. COMPLETE THE STEPS USING YOUR KNOWLEDGE AND SKILL OF THE CIRCUITS SHOWN. CONTACT YOUR LEARNING CENTER INSTRUCTOR IF YOU HAVE ANY QUESTIONS.

SET THE LOAD SELECTOR SWITCH ON THE NIDA 201L LOAD BOX TO VARIABLE LOAD. SET THE COARSE AND FINE VOLTAGE CONTROLS ON THE FRONT PANEL OF THE NIDA 201 POWER SUPPLY FULLY CW. SET THE CURRENT CONTROL ON THE NIDA 201 POWER SUPPLY TO MID-RANGE. THE VARIABLE LOAD CONTROL ON THE NIDA 201L IS SET FOR AN INDICATION OF 1 AMPERE ON THE POWER SUPPLY FRONT PANEL METER. ALL VOLTAGE AND RESISTANCE MEASUREMENTS WILL BE MADE WITH REFERENCE TO GROUND UNLESS THE PRINTED CIRCUIT BOARD IS REMOVED TO MEASURE FRONT TO BACK RESISTANCE RATIOS OR TO MEASURE THE RESISTANCE OF A SPECIFIC RESISTOR.

## STEP ONE - SYMPTOM RECOGNITION

1. Does the equipment energize? \_\_\_\_\_ Yes/No

## STEP TWO - SYMPTOM ELABORATION

1. What do the meters indicate ? (Normal, high, low, zero).
2. Manipulate the voltage and current controls. Do they all perform normally?

## STEP THREE - LIST THE PROBABLE FAULTY FUNCTION(S)

1. There are seven functions in this power supply
  - a. Shunt voltage regulator
  - b. Current limiter
  - c. Primary voltage regulator
  - d. Reference series voltage regulator
  - e. Voltage comparator
  - f. Current regulator
  - g. Output monitoring circuit

## TROUBLESHOOTING PERFORMANCE TEST

## STEP FOUR - LOCALIZE THE FAULTY FUNCTION

1. Verify the probable faulty function by use of test equipment.
2. List the test points where voltages were obtained.
3. Reference voltages are listed in the voltage chart.
4. Which function listed in step three above is the faulty function?

## STEP FIVE - LOCALIZE THE FAULTY CIRCUIT/COMPONENT

1. List the test points where actual voltages were taken.
2. What circuit/component in the faulty function listed in step four is faulty?
3. If you have determined the faulty circuit but not the faulty component proceed to step six.

## STEP SIX - FAILURE ANALYSIS

1. Secure the power and using the Simpson 260 take resistance checks.
  - a. Check front to back ratios on diodes.
  - b. Take continuity checks on printed circuit board foil.
  - c. Capacitors can be shorted or open.
  - d. Resistors can be open.
2. Explain in your own words why the component listed in steps five or six above would cause the symptoms listed in steps one and two of the six step troubleshooting procedure? Write your answer in the space provided below.

TAKE YOUR 6 STEP TROUBLESHOOTING SHEET TO YOUR LEARNING CENTER INSTRUCTOR FOR VERIFICATION AND EVALUATION.

## VOLTAGE/RESISTANCE CHART

The following Voltages and Resistances were taken with the load selector switch on the NIDA 201L load box set to variable load, and the coarse and fine voltage controls and the current control set fully CW. The variable load control on the NIDA 201L is set for an indication of 1 ampere on the power supply front panel meter. All voltages were taken with a DMM and all resistance measurements were taken with a Simpson 260 multimeter and referenced to ground or circuit common.

<u>POINT OF CHECK</u>	<u>VOLTAGE</u>	<u>RESISTANCE</u>
Pin # 7	40.1 VDC	1200 ohms
Pin # 9	36.3 VDC	1700 ohms
Pin # 12	38.2 VDC	1150 ohms
Pin # 14	37.5 VDC	1900 ohms
Pin # 15	37.4 VDC	2800 ohms
Pin # 16	32.0 VDC	575 ohms
Pin # 18	31.2 VDC	30 ohms
Pin # 19	16.4 VDC	1900 ohms
Pin # 20	14.7 VDC	1000 ohms
Pin # 21	14.8 VDC	660 ohms
Pin # 22	14.7 VDC	1000 ohms
Pin # 23	14.8 VDC	660 ohms
V <sub>E</sub> Q5	36.7 VDC	4700 ohms
TP-1	32.6 VDC	1850 ohms
V <sub>B</sub> Q7	15.3 VDC	1600 ohms
V <sub>C</sub> Q7	25.4 VDC	1800 ohms
V <sub>E</sub> Q8 and V <sub>E</sub> Q9	14.2 VDC	160 ohms
V <sub>C</sub> Q8	17.4 VDC	200 ohms
V <sub>B</sub> Q6	34.7 VDC	3800 ohms
V <sub>E</sub> Q6	35.3 VDC	2000 ohms



ANSWER SHEET  
FOR  
PROGRESS CHECK  
LESSON II

Transistor, Voltage and Current Regulators

QUESTION No.

CORRECT ANSWER

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.
- 8.
- 9.
- 10.
- 11.
- 12.
- 13.
- 14.
- 15.
- 16.
- 17.
- 18.
- 19.
- 20.

- a.
- b.
- c.
- b.
- a.
- b.
- a.
- b.
- d.
- d.
- b.
- c.
- d.
- d.
- d.
- c.
- c.
- b.
- a.
- c.

ANSWER SHEET  
FOR  
JOB PROGRAM  
LESSON 2

Transistor, Voltage and Current Regulators

11. 1.0 Amps. 1.5 VDC
- 12.. a. increasing  
b. unregulated
13. 30 VDC 0.8 Amps.
14. a. Remained the same  
b. Decreased  
c. 0.3 Amps.  
d. Yes  
e. 0.3A to 0.8A or 0.5 Amps
18.  $V_C = 26.0$  VDC  
 $V_B = 15.3$  VDC  
 $V_E = 14.8$  VDC
19. 0.5 VDC
21.  $V_C = 25.3$  VDC  
 $V_B = 15.2$  VDC  
 $V_E = 14.7$  VDC
22. 0.5 VDC
24.  $V_C = 26.2$  VDC  
 $V_B = 15.3$  VDC  
 $V_E = 14.8$  VDC
25. 0.5 VDC  
a. 0.00  
b. remained the same
29. 38.8 VDC 0.6A 15 VDC 23.8 VDC
30. a. 37.4 VDC  
b. 15.0 VDC  
c. 22.4 VDC  
d. 1.4 VDC  
e. decreased  
f. Yes

ANSWER SHEET  
FOR  
JOB PROGRAM  
LESSON 2

Transistor, Voltage and Current Regulators

31. a. 41.3 VDC  
b. 15.0 VDC  
c. 26.3 VDC  
d. Yes
32.  $V_C = 16.9$  VDC  
 $V_B = 40.1$  VDC  
 $V_E = 40.7$  VDC
33.  $V_C = 16.9$  VDC  
 $V_B = 37.6$  VDC  
 $V_E = 38.2$  VDC
34. 0.6 VDC
35. 0.6 VDC
36. constant
39. CCW      0.00 VDC      0.67 VDC      0.67 VDC  
0.3A      0.57 VDC      1.76 VDC      1.18 VDC  
0.6A      1.09 VDC      2.29 VDC      1.19 VDC
- a. no  
b. no  
c. There is no voltage across R2 with R5 fully CCW so no current is flowing through it. The transistors Q1 and Q2 are cutoff; or words to that effect.
42. 1.07 VDC
43. Yes
- 46.. 0.68 VDC
48. 4.82 VDC  
a. 4.15 VDC  
b. CCW  
c. CW

# *NOTES*